

Investments in Higher Education and the Economic Performance of OECD Member Countries

Amnon Frenkel and Eran Leck

Faculty of Architecture and Town Planning, and Center for Urban and Regional Studies, Technion-Israel Institute of Technology, Haifa, Israel.

Tel: +972-4-8293956, Fax: +972-4-8294071, E-mail: amnonf@tx.technion.ac.il

Abstract

The research investigates the relationship between investments in higher education and the economic performance of OECD countries through the use of a two-stage regression model and multivariate analysis. The findings suggest that an indirect relationship exists between higher education investments and economic growth. Evidence shows that higher education inputs translate into human capital outputs, and these turn back into inputs, which explain economic growth. The research supports evidence from other studies showing decreasing returns to scale in higher education. The elasticity of GDP per capita with respect to R&D expenditure per student and expenditure on teaching in research universities was found to be fairly large, with constant elasticity measuring 0.78, and point elasticities (when expenditure on teaching is held constant) ranging from 0.04 (Turkey) to 0.84 (Sweden).

Key words: R&D, Higher Education, Economic Growth, OECD

1. Introduction

Higher education is considered to play a key role in contributing to the economic growth of countries. Higher education investments (both in academic research and in teaching) directly affect the economic performance of countries by producing highly skilled, productive workers (university graduates) who integrate into the workforce and contribute to the economic growth process. In addition to the apparent direct productivity benefits of higher education to the economy, there are also indirect benefits, which are expressed by the creation of new knowledge, ideas, and technological and scientific innovations.

The vast majority of empirical macro-economic studies dealing with the association between education and growth (Chatterji, 1988; Romer, 1990; Barro and Lee, 1993; Barro and Sala-i-Martin, 1995) have employed growth regressions based on comparative databases from dozens of developed and developing countries. These studies, for the most part, have tried to explain the association between higher education and economic performance in a direct way, by regressing education indicators (e.g., university enrollment rates, percentage of labor force with an academic degree) against macro-economic variables such as per-capita GDP or total factor productivity.

These econometric studies are problematic in the sense that they simply analyze the relationship between education inputs and economic outputs without analyzing the process linking them, thus making the results prone to causality bias. Furthermore, the mixture of developed and developing countries in the empirical analysis can lead to highly skewed, dubious results regarding the true nature of this relationship.

In this study, we attempt to circumvent these problems by formulating a two-stage model for OECD countries that indirectly estimates the relationship between higher education investments and economic performance through the use of an instrumental indicator representing the quality of human capital in the country. Multivariate regression models are employed only after the two-stage process between higher education and growth is confirmed which rules out a random association between these two variables

The paper is organized as follows. In Section 2 we investigate the role of higher education investments in the economic growth process and review the social and economic contributions of basic university research to regional and national economies. In Section 3, we review specific macro-economic models that aim at estimating the relationship between higher education and economic performance. Section 4 describes the two-stage model, including the methodology used and the research findings from both stages. Section 5 reports the findings of the multivariate regression models and the derived elasticities of output with respect to higher education investments. Section 6 concludes the paper with a discussion of the research findings.

2. Universities as Generator of Economic Growth

A broad consensus exists in the economic growth literature in regard to the positive and significant association between public investments in education and economic growth. Universities and academic research institutions play an important role in contributing to the economic growth of regions and countries, mainly through the diffusion of scientific knowledge and new methods and technologies (Bergman, 1990; Mansfield and Lee, 1996; Martin, 1988). Academic research has a direct contribution to the economy because it fosters a deeper and broader understanding of social and economic phenomena (Sianesi and Reenen, 2003).

Many studies conducted in the past two decades have shown that public investments in higher education yield significant benefits, both direct and indirect, to national economies (Nelson, 1986; Jaffe, 1989; Adams, 1993; Fischer and Varga, 2003). Direct benefits include the enhancement of GDP, employment, and labor productivity and the enlargement of the pool of skilled scientists and engineers. Indirect benefits include such elements as capital investments and the creation and adoption of technological innovations.

There are private and public returns to higher education investments. Private returns express the utility that the individual acquires as a result of his or her investment in higher education (e.g. higher income and a higher probability of remaining in the labor force); the utility to the firm is expressed in larger savings and higher efficiency, achieved by the highly skilled workers that it employs. Public returns to higher education, on the other hand, express the aggregate utility that society and the

economy gain as a result of public investment in higher education and R&D (higher GDP and productivity, a decrease in birth and crime rates, etc.).

Martin et al. (1996) have identified five main types of contributions of higher education to economic growth: Increasing the stock of useful knowledge; Promoting knowledge spillovers; Training highly skilled graduates; Creating methodologies and new scientific tools; Increasing the capability for scientific and technological problem-solving.

The traditional justification for public funding in basic research is that it expands the scientific information or the accumulated knowledge available for firms to draw upon in their technological activities. According to Guellec and van Pottelsberge de la Potterie (2001), economists often ignore the impact that an increased stock of knowledge has on the economy, because new knowledge is not regarded as an output of the national accounts system (as opposed to physical investment in infrastructure, for example), and therefore it is not taken into consideration in the calculation of the GDP.

Anselin et al. (1997) claim that the importance of basic research in a university to the stimulation of technological innovation and higher productivity derives from its characteristic as a public good and the resulting positive externalities to the private sector in the form of knowledge spillovers. Two types of knowledge spillovers have been identified in the literature, geographical spillovers and spillovers across sectors (Griliches, 1995). The former imply benefits for firms located near research centers, other firms and universities, and the latter involve the transfer of technology and knowledge from universities to industry and the economic benefits to firms as a result of these actions.

Many studies have examined the link between the formation of economic agglomerations (especially in the electronics sector) and geographical spillovers. According to Feldman (1993) and Feldman and Audrestch (1999) firms that locate in proximity to universities and R&D centers tend to cluster, and this agglomeration affects the transfer of information between the academy and industry, as well as among the various firms located within the cluster. Two known studies, one conducted by Saxenian (1985) on the growth of Silicon Valley in San Jose,

California, and the other by Miller and Cote (1987) on the technology agglomeration along Route 128 near Boston, Massachusetts, have shown that the evolution of these regions into technological innovation centers was to a large extent due to their proximity to, respectively, Stanford University and MIT. Another study by Saxenian (1994), on Silicon Valley and Route 128, showed that universities located near firms significantly influence their regional innovation capacity. Other studies show that the location choice of high technology firms and start-up companies in proximity to universities and research institutions has enhanced the transfer of knowledge from the academy to industry and, therefore, contributed to the enhancement of regional and national productivity (Markusen, 1985; Nelson, 1986).

A study by Jaffe (1989) estimated the influence of geographical knowledge spillovers in the United States by employing a three-equation model involving patenting, industrial R&D, and basic university research. Using patents as a proxy for innovative output, Jaffe examined the relationship between patents assigned to firms in 29 U.S. states, industrial R&D, and university research. His results demonstrate the existence of spillovers from university research and industrial patenting. He also found a link between industrial R&D and university research at the state level. It seems that university research encourages industrial R&D, but not vice versa (Jaffe 1989; Salter and Martin 2001).

Many studies that examined the economic benefits of higher education investments consider the training of skilled graduates as one of the most important factors in the growth and development of firms. New graduates entering the labor force bring with them the latest knowledge of scientific research, as well as the ability to solve complex problems, conduct research, and develop ideas. They often bring with them enthusiasm and a ‘tacit ability’ to acquire and use knowledge in new and powerful ways, as well (Senker, 1995; Salter and Martin 2001).

The challenges entailed in basic research constantly force researchers to design new methodologies and scientific tools to tackle specific research problems. Some of these methods and tools, which are the most important output of universities, adding to the font of knowledge, may eventually be adopted by industry (Salter and Martin 2001). Firms use scientific and technological knowledge produced in universities in order to improve their productivity and design new products, services, and processes, which

are transformed back into the economy in the form of new employment and growth (Martin, 1998; McMillan and Hamilton, 2003). An example of this particular contribution of universities to the productivity of firms is reported by Mansfield and Lee (1996), who estimated that from 1975-1985, about 10% of all new products and services in the American high-technology sector were directly based on university research.

Another contribution of university research to the economy is its ability to assist industry in scientific and technological problem-solving. Basic research conducted by universities enables technology-oriented firms to integrate various technologies into their production process. The skill-development process of researchers who are involved in basic research (especially graduate students) yields economic benefits, especially when these students, who are equipped with innovative knowledge, move from the academy to industry. The fact that students and researchers who are engaged in basic research excel in solving complex problems often proves itself especially valuable to industry (Patel and Pavitt, 1995; Martin et al., 1996).

3. Investments in Higher Education and R&D, and Economic Growth

Over the past twenty years, the link between higher education investments and economic growth has begun to be more thoroughly researched. The motivation behind these fundamental studies was the development of endogenous growth theory, which has highlighted the human capital factor as the main catalyst for economic growth. The first endogenous growth studies (Romer, 1990; Barro and Lee, 1993; Barro and Sala-i-Martin, 1995) studies employed growth regressions based on comparative databases from 130-200 countries. A typical dependent variable used in such studies was GDP per capita or another productivity variable. Human capital indicators, such as the number of primary and secondary school students, years of schooling, and the percentage of labor force with a high school diploma, usually served as the independent variables in those analyses. Findings from these types of studies by and large show a significant positive linkage between education and growth indicators (Sianesi and Reenen, 2003).

In recent years, many researchers have adopted the econometric growth regression methodology in an attempt to measure the impact of higher education and scientific

research on the economic growth of countries. Chatterji (1988) found a positive and significant association between annual GDP per capita growth and the increased enrollment percentage in higher education institutions between 1960 and 1985 in 98 developed and developing countries. His research has also shown that the contribution of higher education to growth is even higher than the contribution of primary and secondary education, which is in contrast to the findings by Romer (1990) and Barro and Sala-i-Martin (1995). A significant link between basic research (measured by the number of published scientific articles) and the growth in productivity of 18 industries in the United States was found by Adams (1990, 1993). He also identified a 20–30 year lag between scientific publications (the knowledge stock) and productivity growth.

Other econometric studies investigated the relationship between investment in higher education or public R&D investment and economic growth, based on a comparison of OECD countries. McMahon (1993), in his study of 11 OECD countries between 1960 and 1980, found that the contribution of higher education and R&D investment to total factor productivity was very large, comprising 13% of the 19% total productivity growth during this twenty-year period. Recently, Guellec and van Pottelsberge de la Potterieu (2001), in their study of 16 OECD countries between 1980 and 1998, found that if public R&D investments would have been increased by one percent, a 0.17% increase in productivity growth would have followed. This impact on productivity growth was found to be larger in countries where the share of universities (as opposed to government labs) is higher.

The main criticism of the above-mentioned econometric studies is that the relationship between technological change and economic growth is problematic for economic research. It is difficult to find reliable indicators of technological change, and there is an econometric difficulty of drawing conclusions from non-experimental data. Furthermore, these models do not explain the association between higher education (or basic research) and economic performance in a direct way. They simply look at inputs (such as scientific publications) and outputs (firm sales) without analyzing the process linking them (Griliches, 1995; Nelson, 1998).

Mansfield's (1991) research is considered to be one of the path-breaking studies in measuring the economic benefits from basic university research. Using a sample of 76

U.S. firms in seven industries, Mansfield obtained estimates from company R&D managers about the proportion of the firm's products and processes over a 10-year period that could not have been developed without academic research. He found that 11% of all new products and 9% of new processes could not have been developed without a substantial delay were it not for the contribution of academic research. In a follow-up study, the effect was found to be higher: 15% of all new products and 11% of new processes (Mansfield 1991). In total, innovations that could not have developed without academic research accounted for 5% of total sales for the 76 firms studied. Beise and Stahl (1999) applied similar methodology to that of Mansfield in order to investigate the contribution of public research to industrial innovation in Germany. They report that approximately 5% of new product sales could not have developed without academic research. Their research also shows that academic research has a greater impact on new products than on new processes and that small firms are less likely to draw on innovations from universities than are large firms.

Maital et al. (1994) examined the link between scientific and technological excellence and high-technology exports in 12 EU countries. The authors developed a two-stage model of scientific and technological innovation, in which economic inputs (R&D investments) generate scientific and technological outputs (academic publications, citations, and patents). These technological outputs turn back into inputs that explain the scope of high-technology exports. Using this model, the researchers succeeded in proving their hypothesis regarding a significant association between inputs and outputs in both stages.

In the next section of the paper, we apply the two-step model in order to investigate the association between higher education investments and economic growth in OECD countries. This investigation differs from other growth regressions and econometric examinations by its indirect analysis of the process linking higher education inputs and economic outputs.

4. The Two-Stage Model

The first model used to examine our hypothesis regarding a significant and positive association between higher education investments and the economic performance of OECD countries is a two-stage, least-squares regression model. The model assumes

that an indirect link exists between these two indicators. In our analysis, the instrumental indicator, which serves as a bridging indicator, is the country's labor-force quality. The rationale for using this indicator is as follows. In the first stage of the model, higher education investments in technological and scientific research contribute to the training of a skilled, technological labor force (students) that is absorbed into the labor market. In the second stage, the contribution of this technologically skilled labor force is translated into higher productivity and growth rates, expressed by various economic indicators, such as higher per-capita GDP, high-technology exports, and foreign investments.

Stage 1

Let X be a vector of variables x_1, x_2, \dots, x_n that measure the scope of higher education investments and scientific and technological research in the country, and Y a vector of variables y_1, y_2, \dots, y_n that measure the output of these investments as expressed by the quality of the labor force in the country. This association between higher education inputs X and human capital outputs Y can be summed up by the following expression:

$$[1] \quad Y = f(X)$$

Stage 2

In the second stage of the model, the human capital or labor-force quality (Y) indicator turns from an output (dependent variable) back into an input (independent variable), which explains the country's economic growth.

Let Z be a vector of variables, z_1, z_2, \dots, z_n that express various indicators of growth or economic performance of a country, and Y a vector of variables that express various indicators of labor-force quality in that country. The association between labor-force quality (Y) and the economic performance of the country is expressed by the following expression:

$$[2] \quad Z = f(Y)$$

In order to estimate the association between the indicators in Equations 1 and 2, we can use a simple, linear, least-squares regression. Before specifying our empirical findings, however, we should first address the database sources, population sample, and the variables used for each indicator.

Database and sample

The data-collection stage involved work with five different databases because of the need to collect data for three different types of indicators (each containing a few variables) for 30 OECD countries. The best time-series data, spreading over a period of five decades (1960-2004), were *macro-economic indicators* reflecting the economic performance of countries. Macro-economic data were taken from the electronic database of the World Bank (WDI) and from the Science and Technology Indicators of the OECD. *Higher education data* were taken from the electronic databases of UNESCO and the OECD. These data, which reflected the expenditure on higher education and scientific research, were available for only one time period (late 1990s and early 2000's) and supplied information on fewer than 30 OECD countries (there was no information on countries, such as Poland, Hungary, Czech Republic, Slovakia, and Korea, that joined the OECD in the past decade). *Labor-force data* were taken from the International Labor Organization Bureau of Statistics (LABORSTA). These data were also available for only one time period.

The process in which higher education inputs are transformed into labor-force quality outputs, and these back into inputs that explain the economic performance of countries, needs to be measured over a lengthy period of time. However, because of data-availability constraints, it was not possible within the framework of the two-stage model to examine a real temporal procedure that extends over a few decades. The data for the two-stage model, therefore, covers only one point in time (an average of the years 1998-2000). Despite this limitation, it is possible in our opinion to define this model as a "quasi-temporal procedure." We assume that the investments in inputs are not subject to acute variations, and therefore the bias caused by the use of only one time period is not significant.

Model's variables

Higher Education Variables (X)

The higher education indicator included four variables that have supplied a good indication of the scope of a country's investments in research universities, students, and technological and scientific research. We used normalized variables [e.g., expenditure as a percentage of GDP, relative percentage of population or workforce, expenditure in converted U.S. dollars in terms of purchasing power parity (PPP)] in

order to minimize sampling bias and enable comparisons among countries. The four higher education variables and their abbreviations are as follows:

- Total expenditure per student in research universities (Type A tertiary education) in U.S. dollars, converted, using PPPs (EX_STUD_UNI).
- Number of researchers in R&D per 100,000 residents (RES_R&D_100K).
- Expenditure per student on R&D in U.S. dollars, converted, using PPPs (EX_STUD_R&D).
- Total expenditure on R&D as a percentage of GDP (EX_R&D_GDP)¹.

Human Capital Variables (Y)

The Y indicator serves in the two-stage model as a bridging indicator between higher education and economic variables. This indicator includes two variables:

- The percentage of employees in the computer field² of the total number of employed persons in the labor force (COMP).
- The percentage of employees in the scientific and technological fields³ of the total number of employed persons in the labor force (SCI_ENG) .

These two variables, which express the scope of employed persons in technological, scientific, and engineering fields, were chosen owing to their ability to serve as good proxies for the quality of productive human capital in the various countries.

Economic Growth Variables (Z)

The third indicator Z measures the economic performance of OECD countries. It includes four variables:

- Foreign direct investments as a percentage of GDP (INV_GDP).
- Expenditure on communication and information technology as a percentage of per-capita GDP (EX_COM_TECH).
- GDP per capita, constant 1995 US\$ (GDP_CAP).

¹ Not including military R&D.

² The percentage of employees in the computer field includes computer engineers, electrical and electronics engineers, system analysts.

³ The percentage of employees in the scientific and engineering fields relates to the following fields: Natural and Life Sciences, Physical Sciences, Mathematics, Statistics, Architecture, and all the Engineering fields. The aggregation of the engineering and scientific fields into one variable has enabled us to obtain a higher level of variance.

- Ratio of high-technology exports to total exports (HI-TECH_EXP) .

Findings

Stage 1: Human Capital Quality as a Function of Higher Education Investments

In the first stage of the model, the higher education and scientific research inputs are "translated" into labor-force quality outputs. Table 1 and Figures 1-3 present the statistical association between three variables of higher education investments and two variables of labor-force quality in the OECD countries and Israel. As can be seen, there is a relatively strong and positive link between the higher education inputs and the labor-force quality outputs. This association is, however, much more robust between the higher education inputs and the percentage of employees in the computer field than it is with the percentage of employees in scientific and technological fields.

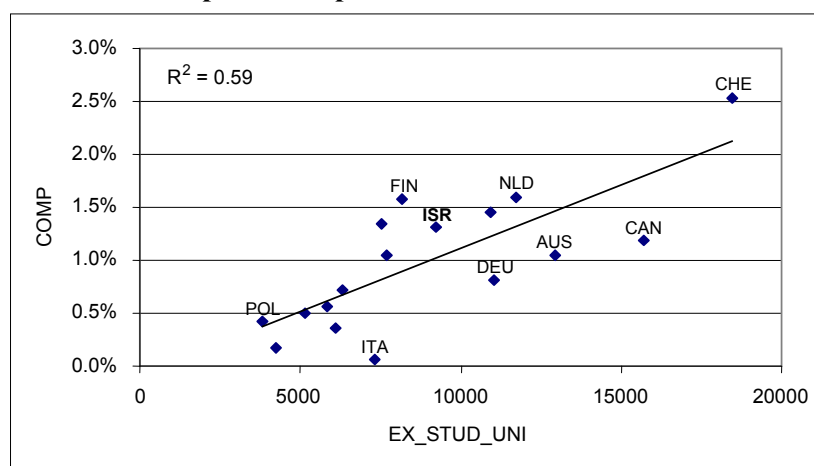
Table 1: Regression Results – Stage 1

		X variables	N*	t-value	R ²	P
Y variables	COMP	EX_STUD_UNI	17	4.67	0.59	P<0.001
		EX_STUD_R&D	20	4.36	0.51	P<0.001
		RES_R&D_100K	23	4.98	0.54	P<0.001
	SCI_ENG	EX_STUD_UNI	18	2.54	0.29	P<0.05
		EX_STUD_R&D	19	3.45	0.41	P<0.01
		RES_R&D_100K	25	4.83	0.35	P<0.01

* The number of observations (OECD countries) varies according to data availability.

Figure 1 presents the percentage of employees in the computer field as a function of total expenditure per student (in U.S. dollars, PPP) in research universities. As can be seen, the link between the total expenditure per student in research universities (a variable expressing the scope of public and private investments in research universities in the country) and the percentage of employees in the computer field ($R^2=0.59$) is much more robust than the link between this explanatory variable and the percentage of employees in scientific and technological fields [$(R^2=0.29)$; see Table 1].

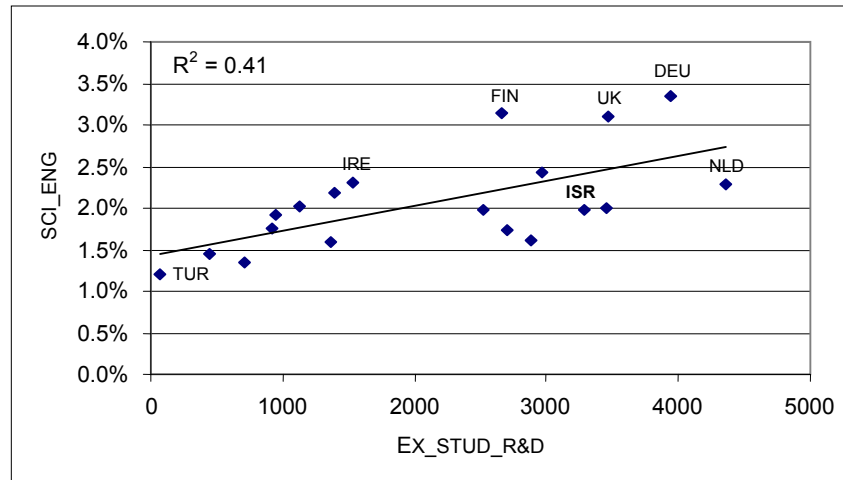
Figure 1: Percentage of employees in the computer field as a function of total expenditure per student in research universities



Switzerland is located in the figure above the linear trend-line representing OECD countries, showing very high per-student expenditures, as well as high outputs of skilled labor force (employees in the computer field). In contrast to Switzerland, the per-student expenditure and percentage of employees in the computer field in Poland and Italy are very low. The position of Finland is especially interesting because of the fact that despite its relatively average per-student expenditures, compared to other OECD countries, it is characterized by a high percentage of employees in the computer field of the country's total employed labor force. This finding possibly indicates Finland's greater efficiency, since it is apparently able to produce greater output from its technologically skilled employees with relatively lower investments.

Similar significant statistical associations were found when the expenditure-per-student variable was substituted with another variable – the expenditure per student on R&D (in U.S. dollars, PPP) in research universities. The latter findings show that the more the country invests in universities' R&D, the greater will be the percentage of employees in the computer, scientific, and technological fields. The expenditure on R&D in research universities explains roughly 51% of the variance in the percentage of employees in the computer field (Table 1) and about 41% of the variance in the percentage of employees in scientific and technological fields (see Table 1 and Figure 2).

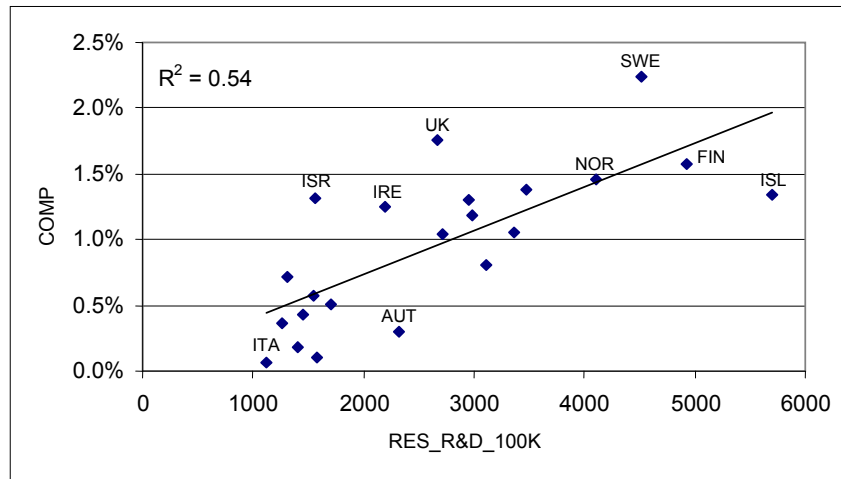
Figure 2: Percentage of employees in scientific and technological fields as a function of the expenditure per student on R&D



Germany and Great Britain are characterized by high expenditures on R&D and by a high percentage of employees in scientific and technological fields (Figure 2). Finland is by far the most efficient country. Although it invests less on R&D in research universities (per student), the percentage of its employees in scientific and technological fields is still very high. An interesting finding is the relatively low positioning of Ireland, which in the last 15 years has become one of the world's most important technology centers. This finding, however, is not that surprising, given that Ireland's relative advantage in technological field centers lies in technological manufacturing, not in scientific and technological R&D (Roper and Frenkel, 2000; Frenkel, 2003).

In Figure 3, the explanatory variable was replaced by the number of researchers in R&D per 100,000 residents. This variable is considered to be a good proxy for a country's scope of investment in higher education because of the fact that R&D researchers constitute an output of the higher education system. Regression results show once again a positive and robust association between higher education inputs and labor-force quality outputs. The location of Sweden in this particular case especially stands out, showing both a large number of researchers in R&D per 100,000 residents and a high percentage of employees in the computer field.

Figure 3: Percentage of employees in the computer field as a function of the number of researchers in R&D per 100,000 residents



Stage 2: Economic Performance as a Function of Human Capital Quality

In the second stage of the two-stage model, the outputs obtained in the first stage (labor-force quality) are transformed into inputs that explain the economic performance of OECD countries. Table 2 and Figures 4-6 present the statistical associations between the two indicators of labor-force quality and the four indicators of economic performance in OECD countries and Israel.

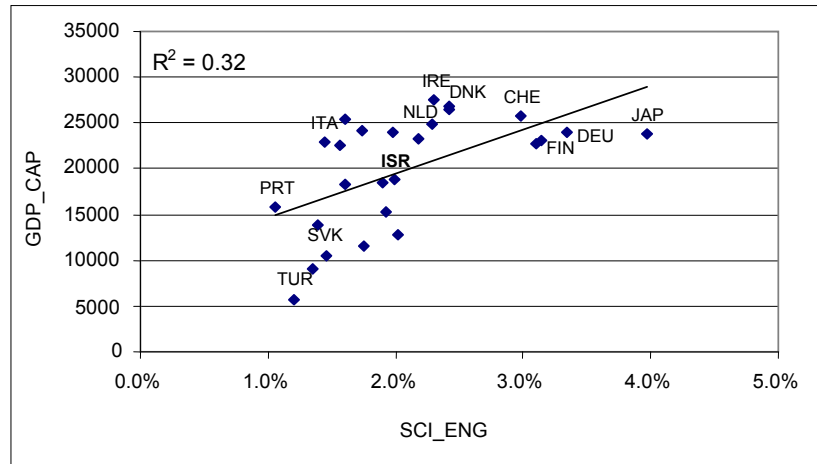
Table 2: Regression Results – Stage 2

		Y variables	N*	t-value	R ²	P
Z variables	INV_GDP	COMP	27	3.64	0.35	P<0.01
	EX_COM_TECH		26	6.41	0.65	P<0.001
	HI-TECH_EXP	SCI_ENG	27	3.39	0.32	P<0.01
	GDP_CAP		26	3.36	0.32	P<0.01
	INV_GDP		27	3.60	0.37	P<0.001
	EX_COM_TECH		25	4.71	0.49	P<0.001

Figure 4 presents the association between the percentage of employees in scientific and technological fields and per-capita GDP. There is a positive and significant link between these two variables ($R^2=0.32$). Japan, Germany, Finland, and Switzerland are located in the top-right corner of the chart. This finding suggests that these countries are able to convert their high human capital inputs into a high level of economic

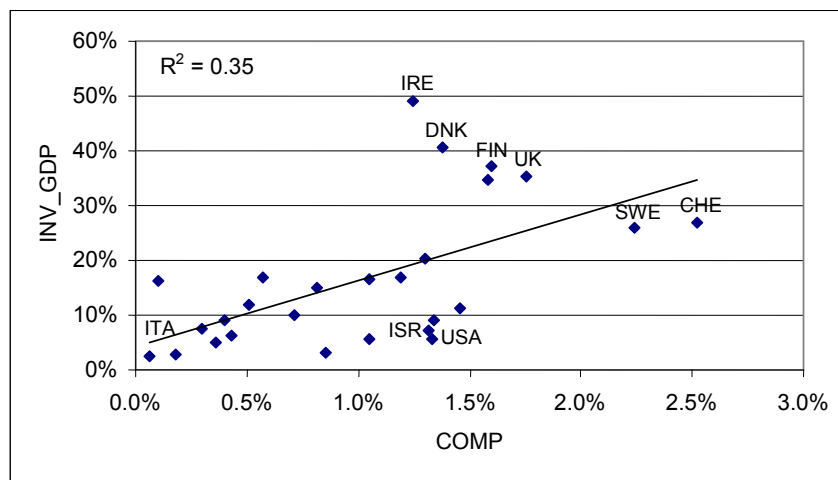
output. Countries such as Denmark, the Netherlands, and Ireland are even more efficient, producing a similar level of economic output while using fewer human capital inputs.

Figure 4: GDP per capita as a function of the percentage of employees in scientific and technological fields



The data presented in Table 2 and in Figure 5 show a positive and significant link between the two human capital indicators (percentage of employees in the computer-related professions, percentage of employees in scientific and technological fields) and the percentage of direct foreign investments (as a percentage of GDP). The linear model explains, respectively, 35% (see Table 2 and Figure 5) and 38% (Table 2) of the variance in direct foreign investments.

Figure 5: Foreign direct investments (FDI) as a function of the percentage of employees in the computer field

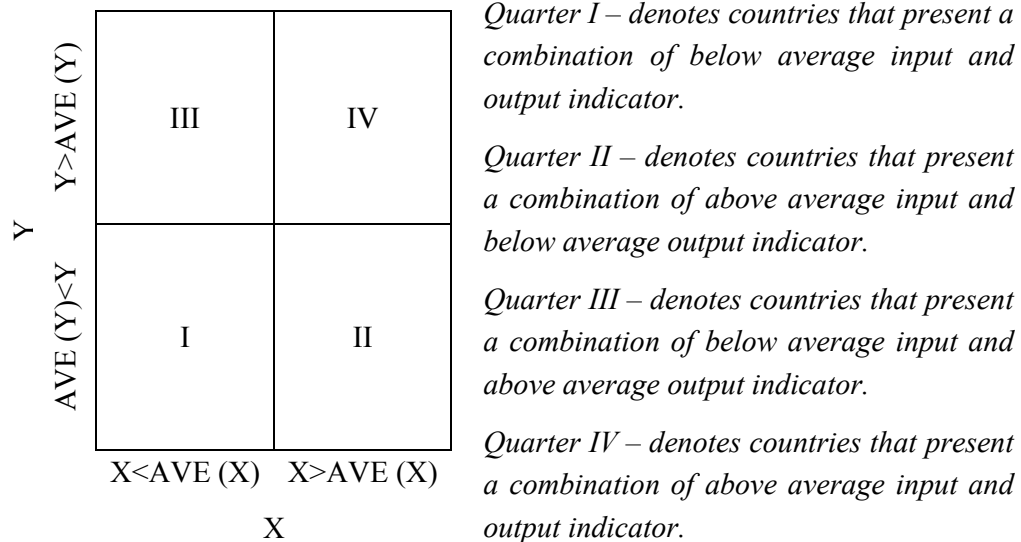


Small countries like Switzerland, Sweden, and Finland are characterized by a high rate of direct foreign investments (Figure 5). The location of Ireland is unique in relation to other OECD countries: it is characterized by an average rate of employees in the computer-related professions but an extremely high rate of foreign investments.

The linkage between the two stages of the model

The findings reported above have shown, on the one hand, a positive and significant relationship between higher education (X) and human capital variables (Y) and, on the other hand, robust associations between human capital and economic growth variables (Z). The question is, Does a significant and positive association also exist between higher education and economic performance? This association between the X and Z variables can exist only if the location of countries in the first set ($X*Y$) is similar to the positioning of countries in the second set ($Y*Z$). In order to test our hypothesis, we created a platform that has enabled us to compare the positioning of countries in both stages of the model. This was accomplished by dividing the two-dimensional space of the scatter charts into four quarters (see Figure 6).

Figure 6: Location of OECD countries, by quarters



The assignment of a country to a particular quarter is a function of the combination of the input indicator (independent variable) and output variable (dependent variable). The division of the two-dimensional space into four quarters was achieved by drawing

a vertical line from the mean value of the input indicator ("X" axis) and a horizontal line from the mean value of the output variable ("Y" axis).

In order to test the relationship between the first and second stages of the model, a representative example (of the thirty-two possible combinations, multiplication of the number of variables – $4 \times 2 \times 4$) is given (Figure 7a-7b). The set of charts presents the association between the expenditure on R&D in research universities (normalized by the number of students) (X) and the percentage of employees in the computer field (Y), and between this percentage and per-capita GDP in terms of purchasing power parity (Z).

Figure 7a - Position of countries in stage 1: Expenditure on R&D in research universities * Percentage of employees in the computer field

COMP (Y)	Y > AVE (Y)	FRA, IRE, USA	AUS, BEL, CAN, DNK, FIN, NLD, SWE, UK, ISR
	Y < AVE (Y)	POL, SVK, GRC, HUN, CZE, ESP	AUT, DEU
		X < AVE (X)	X > AVE (X)
		EX_STUD_R&D (X)	

Figure 7b - Position of countries in stage 2: Percentage of employees in the computer field * GDP per capita PPP

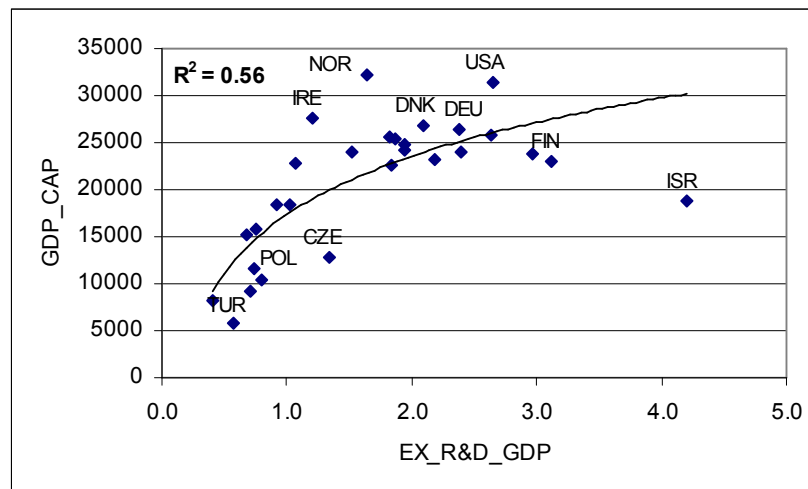
GDP_CAP (Z)	Z > AVE (Z)	AUT, DEU	AUS, BEL, CAN, DNK, FIN, NLD, SWE, UK, FRA, IRE, USA
	Z < AVE (Z)	POL, SVK, GRC, HUN, CZE, ESP	ISR
		Y < AVE (Y)	Y > AVE (Y)
		COMP (Y)	

As can be seen from Figures 7a and 7b, 75%-85% of the observations (countries) are positioned in the first (bottom-left) and fourth (top-right) quarters. This finding is consistent with the existence of a positive linear association among variables. All countries located in the first stage of the model in the first quarter (countries showing poor performance) are also positioned in this quarter in the second stage. Eight of the nine original countries that were located in the fourth quarter (countries showing strong performance) in the first stage of the model are also positioned in this quarter in the second stage (Israel drops from the fourth to the second quarter; France,

Ireland, and the USA climb from the third to the fourth quarter; Austria and Germany change positioned from the second to the third quarter).

The finding indicates the significant role that investment in R&D in research universities has on the economic performance of a country. These findings are even more prominent with respect to the total investment in R&D in the country. Figure 8 presents a significant logistical association ($R^2=0.56$, $P<0.01$) between the total expenditure on R&D as a percentage of GDP and per-capita GDP (PPP). As can be seen, Israel invests a sum of money equivalent to 4.2% of its GDP in R&D, a higher percentage than any other country. This high rate of investment, however, is not reflected in Israel's per-capita GDP, which is significantly lower than most OECD countries. Norway and Ireland can be seen as "mirror images" of Israel. They invest little in R&D relative to their GDP but enjoy high GDP per capita (see similar trends in Figures 7a and 7b).

Figure 8: GDP per capita as a function of the expenditure on R&D as a percentage of GDP



The findings presented in Figures 7a and 7b, which demonstrate a relatively high similarity in the location of the countries in both stages of the model, support our hypothesis regarding a two-stage process between higher education investments in OECD countries and their economic growth. The output of the first stage of the model, reflected in the quality of a country's human capital (a function of higher education investments), indeed transforms into an input that explains its economic performance in the second stage of the model.

Multivariate model

The second model used to estimate the association between higher education investments and the economic performance of OECD countries is a multivariate regression model. The model directly estimates the association between these two indicators, without the use of a bridging indicator. It is important to note that the multivariate regression model was used only after the main hypothesis of the two-stage model, that a significant and non-random association exists between higher education and growth, was reaffirmed.

Model specification

Let X be a vector of variables measuring the scope of higher education, scientific, and technological investments in OECD countries, and let Y be a single vector measuring the outputs of these investments. The output Y , indicating the growth or economic performance of OECD countries, is a function of the linear combinations of higher education indicators, represented by the vectors $X_1 \dots X_n$:

$$[3] Y=f(X_1, X_2 \dots X_n)$$

Multivariate regression variables

The list of independent variables (X), representing the scope of higher education investments in OECD countries, and of dependent variables (Y), indicating the growth or economic performance of these countries, are presented in Table 3. The higher education list contains six variables, three of which are new (marked with an asterisk) and were not used in the two-stage model. The three dependent variables, shown at the bottom of Table 3, are identical to those used in the two-stage model¹.

¹ The data sources for the multivariate regression model are identical to those used in the two-stage model. The higher education variables pertain to data from 1998-1999, and the economic growth variables relate to data from 2000-2001 (the data were available only for these years).

Table 3: Independent and dependent variables in the model

Higher Education variables	Variable abbreviation (X)
Total expenditure on higher education institutions as a percentage of per-capita GDP *	EX_I_GDP_TOT
Expenditure on R&D in higher education institutions as a percentage of GDP*	EX_I_R&D
Expenditure on instruction in higher education institutions as a percentage of GDP*	EX_I_TEA
Total expenditure per student in research universities (Type A, tertiary education) in U.S dollars, converted, using PPPs	EX_STUD_UNI
Expenditure on R&D in research universities (per student) in U.S. dollars, converted, using PPPs	EX_STUD_R&D
Number of researchers in R&D per 100,000 residents	RES_R&D_100K
Economic Growth & Performance variables	Variable abbreviation (Y)
GDP per capita, constant 1995 US\$, PPP	GDP_CAP
Ratio of high-technology exports of total exports	HI-TECH_EXP
Expenditure on communication and information technology as a percentage of per-capita GDP	EX_COM_TECH

* New variables not used in the two-stage model.

Findings

We examined different statistical associations between higher education variables and a single dependent economic growth variable in the framework of the multivariate regression model. Prior to running the statistical tests, we carried out tests for multicollinearity in order to rule out dependency between independent variables in the model. The regression results are presented in Tables 4-7, which are organized by the combination of independent variables with each of the two dependent variables.

Table 4 presents three different regression models (A-C), in which higher education variables are examined against per-capita GDP in terms of purchasing power parity. As can be seen from the table, a strong positive and statistically significant link exists between the higher education indicators and per-capita GDP. The results of Model A show a very high relationship between the total expenditure per student in research universities and the number of researchers in R&D per 100,000 residents in the country, on the one hand, and per-capita GDP, on the other hand ($R^2=0.74$). Another important higher education variable that was found to be highly correlated with per-capita GDP is the expenditure on instruction in higher education institutions as a

percentage of GDP and the investment in R&D in research universities (normalized by the number of students) (Model B). The results show that these two variables explain about 63% of the variance in per-capita GDP.

Model B is of particular interest in that it shows how the two main activities of universities—teaching and research— together contribute to the enhancement of per-capita GDP. It seems that a high level of education and professional training, which are both a function of the investment in higher education instruction, contributes to the creation of a technologically and scientifically skilled work force that integrates into the labor market and contributes to its growth. The contribution of academic research to GDP enhancement can be explained by the fact that it advances technological improvements and a deeper understanding of economic processes (see Boarland et al., 2000). In addition to this direct impact, academic research also exerts indirect externalities on the economy in the form of information spillovers. This phenomenon, which is characterized by the transfer of scientific and technological knowledge from the academy to private firms, serves as a means to enhance their profits (Audretsch and Feldman, 1996; Boarland et al., 2000).

A similar finding, although less statistically significant, is presented in Model C (the second explanatory variable was swapped for another R&D variable - total expenditure on R&D as a percentage of GDP), in which the two independent variables explain roughly 56% of the variance in per-capita GDP.

Table 4: Multivariate models describing the association between higher education variables and per-capita GDP (PPP)

Model	Independent variables	Beta	t-value	R ²	N
A	(Constant)	5208.4	2.99**	0.74	18
	EX_STUD_UNI	1.08	3.20**		
	RES_R&D_100K	2.07	3.62*		
B	(Constant)	4772.2	1.49	0.63	21
	EX_STUD_R&D	2.8	4.30*		
	EX_I_TEA	9070.3	3.10**		
C	(Constant)	4872.1	1.37	0.56	21
	EX_I_TEA	8097.4	2.49**		
	EX_I_R&D	22882	3.52*		

* P<0.01 **P<0.05

In Model D (presented in Table 5), the dependent variable is replaced by another variable, expenditure on communication and information technology as a percentage of per-capita GDP. The model shows a very strong and significant association ($R^2=0.79$) between the total expenditure on higher education institutions as a percentage of per-capita GDP and the expenditure on R&D in research universities on the one hand, and the dependent variable (Economic growth) on the other hand.

Table 5: Multivariate model - higher education variables and the expenditure on communication and information technology

Model	Independent variables	Beta	t-value	R ²	Model
D	(Constant)	-505.1	-1.69	0.79	21
	EX_I_GDP_TOT	943.5	3.79*		
	EX_STUD_R&D	0.3	4.58*		

* P<0.01

The finding obtained from model D is not surprising, given the deep cooperation that exists between research universities and industry (Martin, 1998; Martin and Trudeau, 1998; Shefer and Frenkel, 2003).

The elasticity of output

Table 6 presents per-capita GDP elasticity with respect to the investment in R&D in research universities (per student) and to the expenditure on instruction in higher education institutions. The elasticity shows the effect of a one percent increase in higher education inputs on the percentage change in per-capita GDP.. Model E is actually a log-linear of model B, representing a homogenous Cobb-Douglas¹ type production function. As can be seen from the table, the log-linear model is extremely significant, explaining about 86% of the variance. The model's homogeneity level is lower than one (the combination of the two coefficients in the model yields an elasticity of 0.78), suggesting a decreasing return to scale in education. A one percent increase in expenditure on R&D (per student) in research universities and a one percent increase in expenditure on instruction in higher education institutions (measured as a percentage of GDP) may contribute to a rise of 0.78% in the GDP.

¹ $Y_{(GDP_CAP)} = A * TEA^{\alpha} * R\&D^{1-\alpha}$

Table 6: GDP per capita PPP as a function of the expenditures on R&D and instruction in research universities (log-linear model)

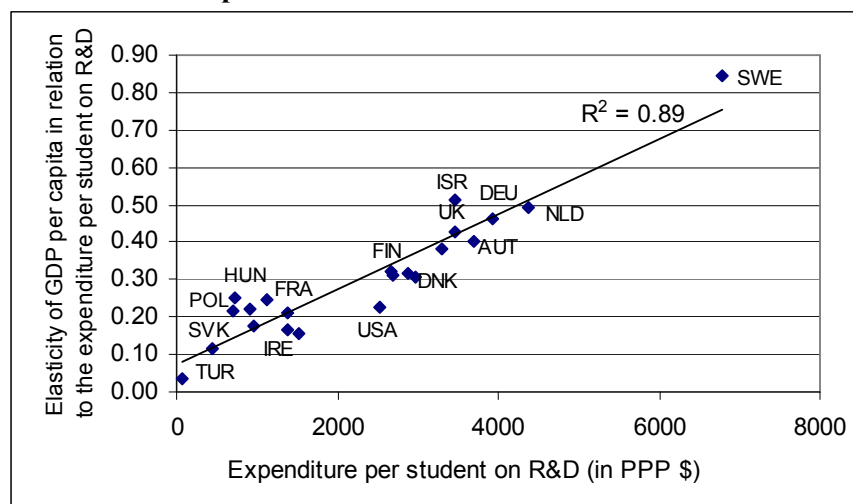
Model	Independent variables	Beta	t-value	R ²	Model
E	(Constant)	6.96	20.4*	0.86	21
	EX_I TEA	0.39	2.9*		
	EX_STUD_R&D	0.39	8.6*		

*P<0.01

Figure 9 presents the point elasticities for model E, derived by a linear model. This linear regression model presents the elasticity of the per-capita GDP in relation to the expenditure on R&D in research universities (per student) when the other input in the model (expenditure on instruction in higher education institutions) is held constant.

The linear model is statistically significant ($P < 0.01$), explaining roughly 89% of the variance. The point elasticities in the model range from 0.04 in the case of Turkey to 0.84 in the case of Sweden, with most OECD countries found in the 0.2-0.5 elasticity range. This finding is consistent with the homogeneity level, or the constant elasticity shared by all OECD countries, which was found in the log-linear model to be around 0.4. In the Swedish case, for example, the scale elasticity derived suggests that a 1% increase in the expenditure on R&D in Swedish research universities could raise Sweden's per-capita GDP by 0.84%.

Figure 9: Point Elasticities - per-capita GDP in relation to the expenditure on R&D in research universities



Two interesting findings emerge from the analysis of Figure 9, which shows a nearly perfect linear association. The first finding has a clear spatial dimension, with Western European countries (e.g., Sweden, Germany, the Netherlands, UK, Austria, Finland) presenting much higher point elasticities than Eastern European countries (Hungary, Poland, Slovakia and Turkey). The second finding, which is not as apparent as the East-West dichotomy, shows that by and large, smaller countries (Sweden, Israel, the Netherlands, Austria, and Finland) have higher point elasticities than do big countries (United States, France). It is possible that smaller countries are more productive in utilizing their university R&D investments, thus being able to achieve higher per-capita output.

6. Conclusion

The present study investigated the association between higher education investments and the economic growth of OECD member countries. Two types of models were used in the analysis in order to test the hypothesis regarding a positive link between higher education inputs and economic output: a two-stage regression model, which tested this hypothesis indirectly by the use of an instrumental variable, expressed by the work-force quality in the country; and a set of multivariate regression models, which directly investigated this link only after the main hypothesis of the two-stage model was reaffirmed and which showed a significant and non-random association between these two indicators.

The findings of the first model, which demonstrated a relatively high similarity in the location of the countries in stage 1 and stage 2 of the model, support our hypothesis regarding a two-stage process between higher education investments and economic growth. The output of the first stage of the model, reflected in the quality of the human capital in the country (a function of higher education investments), indeed transforms in second stage of the model into an input that explains the economic performance of the countries.

The results of the multivariate regression models show that higher education investments and scientific and technological research make a significant contribution to the economic performance of OECD countries. The two main activities of universities – teaching and research--were found to be connected to the ability of

OECD countries to enhance their per-capita GDP. The data show that the more the country invests in university R&D and the more it trains students in R&D, the higher will be the ratio of employees in the technological and scientific fields in that country.

An important finding of the study is that small countries, such as Ireland, Sweden, the Netherlands, Austria, and Finland, are more productive in utilizing their higher education and university R&D investments than are big countries, such as the United States, France, Japan, Great Britain, and Italy. Small countries see a vital need to constantly reassess the degree of innovation of their economies in order to sustain economic competitiveness. Because of economies of scale, they cannot embrace the strategies of big countries and compete with them solely on a quantity or cost basis. Small countries must think imaginatively in order to overcome their own limitations, whether in size or resource. They have to leverage their own strengths, find niches in which they can build peaks of excellence, and more efficiently utilize their human-capital resources to maintain relevance in this age of fierce global competition. Thus, smaller countries perceive knowledge creation, human talent, and innovation as key determinants of long-term growth and prosperity.

In this contemporary era of information-technology and globalization, investments in a technologically skilled labor force become a feature of paramount importance in national and strategic economic planning. Countries that were only recently part of the developing world are adopting policies that advocate massive investments in higher education, especially in the scientific and technological fields. Substantial investments in higher education enable even disadvantaged countries (in terms of population size, natural resources, volatile political situation, etc.) to take part in the global race for economic prosperity. Forging the nexus between high-quality academic teaching, university R&D, and innovation should constitute a key policy goal for these countries to meet their economic ends and achieve higher levels of well being.

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